THE ERIE WATER WORKS PLANT[1]

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The first water works plant which supplied the city of Erie was completed in the fall of 1841 and took its supply from what is known as Reeds Springs, which was piped into the city, or town as it was at that time, through pipe made by boring logs, no regard being paid to the contour of the exterior. These works were in operation until the completion of what might be termed the nucleus of the present plant, which first supplied water in 1872.

This nucleus plant took its supply from a crib a few hundred feet out, in what is now known as the bay or harbor, and is formed by a narrow neck of land known as the peninsula.

The original engines (two in number) were the beam type, Cornish Bull Pumps and notwithstanding that they delivered into a reservoir, a standpipe was constructed adjacent to the pump station to soften this action. The first installment of pipe cost $78.25 per ton. The present reservoir, which was built in 1874, having a capacity of 33,000,000 gallons cost but $125,000. In connection with this history it is interesting to note that one of the first board of commissioners was John Gensheimer, father of the present secretary of water works commissioners in the city of Erie.

This water works plant was naturally extended from time to time in its carrying and distributing mains and by the addition of boilers and pumps. The first supplement to the beam type pumps was an 8,000,000-gallon Gaskill, and later a 12,000,000-gallon Worthington high duty, which was again supplemented by an 8,000,000-gallon Worthington high duty, all horizontals.

To those familiar with the geography of Erie it will be known that the bay, from which the supply was taken, is connected only with the outer lake by a narrow dredged channel created and kept open by the United States government for navigation purposes, and that into

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this bay was then poured the entire, and even to this day the major portion of all of the sewage of the city of Erie.

The first steps toward the betterment of this supply was taken in July, 1904, when a contract was let for a 60-inch steel intake, which extended across the bay, the peninsula, and 5000 feet beyond into Lake Erie, terminating in a submerged crib, the total length being 17,000 feet. This improvement was completed in 1895 and its being put in service, naturally, greatly improved the quality of water supplied to the inhabitants of Erie.

The above mentioned reservoir was at an elevation sufficient to supply for many years the entire city, but as the city is built on a gradual slope back from Lake Erie, added years brought a growth up to and beyond the reservoir. To supply these higher elevations the mains were extended, and to all of the territory which was unable to receive an adequate pressure from the reservoir the water was pumped directly into the mains. The last-purchased Worthington or Gaskill alternated on this service, being operated constantly at nearly their capacity. Provisions for the excess were made through the medium of relief valves discharging into the low service or reservoir system.

The above describes the condition of the water works plant at the beginning of the year 1911, when a severe epidemic of typhoid visited that city. The total cases, aggregating 1060, resulted in 135 deaths.

It was by virtue of this epidemic that the firm, of which one of the authors of this paper is senior member, was employed to make a study and recommend means for the purification and betterment of Erie's water supply.

The usual study of population, prospective growth, and consumption was made, when naturally the amount necessary for the future became dependent upon whether or not the then existing flat rate would be continued indefinitely, or whether meters would be installed. The former was decided upon, at least as long as the then existing intake would provide sufficient capacity for the supply.

One of the first studies made was to ascertain the capacity of this intake. In the condition in which it then was, it was found to be approximately 20,000,000 gallons, its capacity being limited by a high place near the bay shore, not far from the pumping station. Experiments also pointed to the fact that with pumps located at approximately lake level and a siphon end provided for this intake

and means for removing the air at the high point, all of which would cost but a few thousand dollars, its capacity could be increased from 20,000,000 to 40,000,000 gallons daily. This 40,000,000 gallons was to be the maximum capacity to which flat rates would be employed. It was the intention then, as the peak loads approached this amount, to apply meters to the extent of keeping the demand well within the intake capacity, or 40,000,000 gallons.

The further result of the engineers' study was that there should be added to the plant, at once, the following units:

A 24,000,000 gallon filter plant.

A 20,000,000 gallon high service vertical crank and fly-wheel pumping engine.

Two 20,000,000 gallon engine driven centrifugal low service pumping engines.

A new boiler plant capable of delivering steam at a much higher pressure than the then existing plant, and also providing superheat for the steam.

Coal and ash handling equipment.

A new pump station building.

A standpipe for high service.

This additional equipment was estimated to cost approximately $600,000.

The view shown in figure 1, taken across the swimming pool, gives a good idea of the exterior architecture of the new pumping station, the old boiler house, and the stack.

The 20,000,000 gallon high service engine was built by the Bethlehem Steel Company, which showed a test duty of 205,000,000 foot pounds for each 1000 pounds of commercially dry steam consumed, ranks high in efficiency among the existing pumping engines of the country.

The contract for the low service pumping engines was placed with the R. D. Wood and Company, the pumps being built by the Camden Iron Works and the engines, which were vertical Marine type, cross-compound condensing, by the Shephard Engineering Company of Williamsport, Pa.

With respect to the filter plant, we shall burden you only with the features that, to the best of our knowledge, are different. The first of these is the architecture brought out by figure 2, being in a measure a birds-eye view taken from the hill above the pumping station at the boiler house end, and incorporates also the State Fisheries Building in the rear of the covered settling basins. A

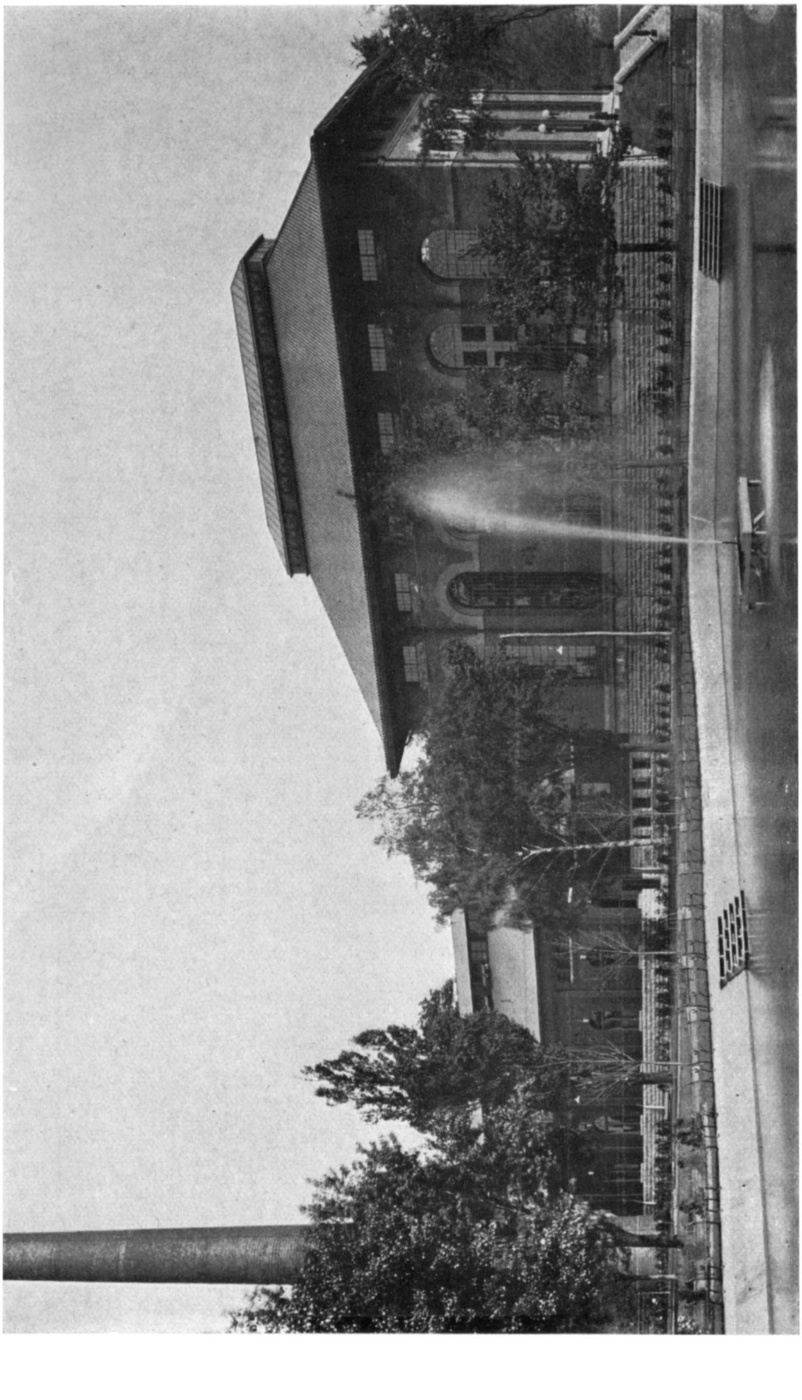

Fig. 1

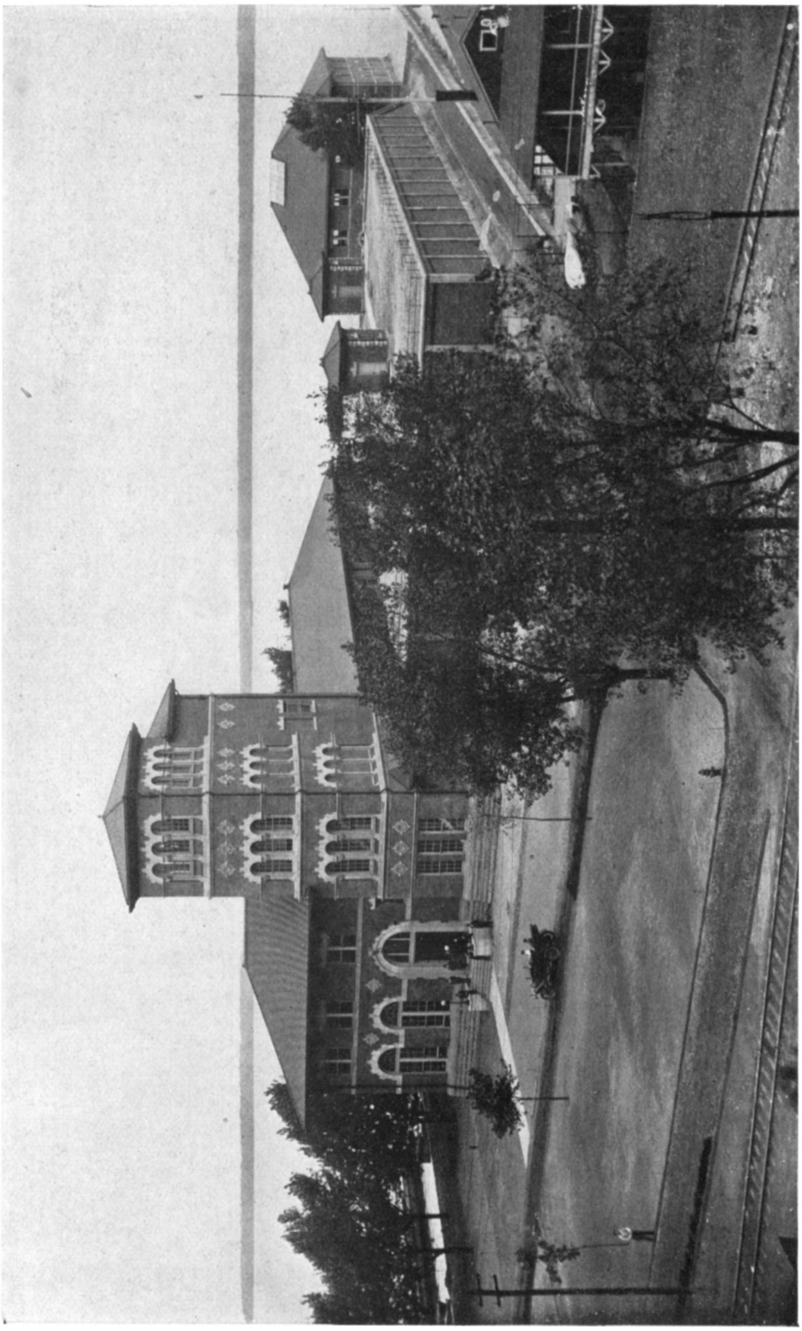

Fig. 2

feature of this that we believe to be different from most filter plants of this size and larger is the architecture, the quality of which we leave the reader to judge for himself.

This filter plant in its original design was predicated on two days natural sedimentation to be obtained from a sedimentation basin, on the peninsula which naturally permits water to be delivered to the coagulant basins at a very low turbidity.

A second feature in which these filters differ from others is in the collecting system, wherein the false bottom type of collecting and wash distribution is employed, these false bottoms being constructed of steel. It is fair to say, however, that in later designs built at other places, reinforced concrete has been substituted for this all steel design. The advantage or disadvantage of this false bottom system is what here interests us most.

These filters have been in operation since 1911, during which time neither sand nor gravel has been removed from either of the twelve 2,000,000-gallon unit tubs. Surface indications, as well as other investigations made by digging through, indicate that no clogging whatsoever has yet taken place, the wash pressure is as low as the day the filters were started, the wash water distribution apparently perfect, and the efficiency of individual beds in the combined plant beyond question.

It would, however, be unfair to attribute the above results entirely to the design. The designer can here speak for the quality of the operation, due wholly to the vigilance of his collaborator in the preparation of this paper, in that its operation has been masterful and at all times as nearly perfect as the most exacting could hope for.

Figure 3 shows the main entrance to the filter building and, most prominently, what is known as the master control table, whereon are the dials of the venturi meter, indicating the rate of flow to the settling basins; gages showing the height of water in the settling basin and the clearwell; back of these, though difficult of outline, the indicators showing the turbidity of the raw and filtered water, and beyond, and out of sight, due to the venturi meter frame, the master control lever by means of which the operator may at any time, by a slight movement, vary uniformly the output of all of the filters evenly and consequently control the rate at which filtered water is being delivered to the clear water basin.

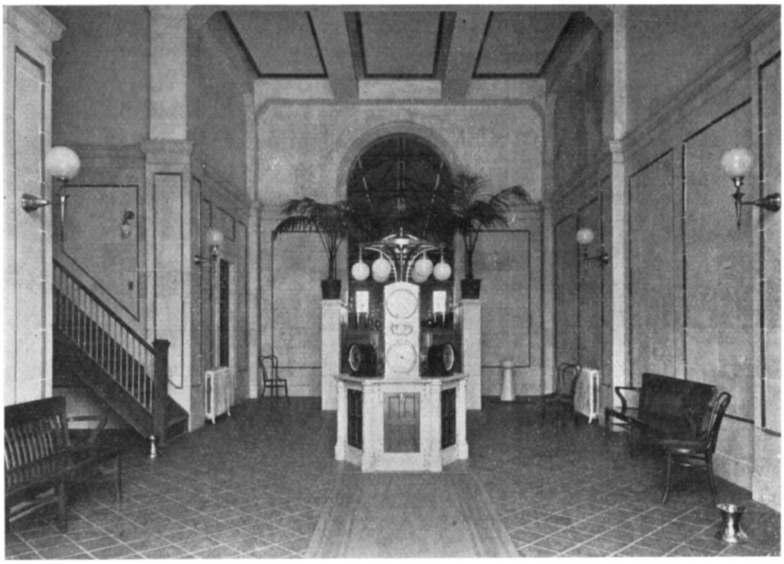

Fig. 3

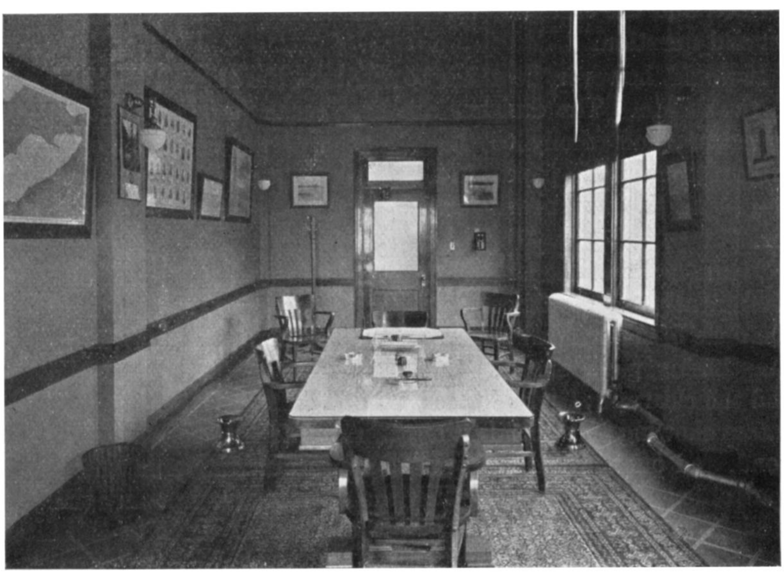

Fig. 4

Figure 4 is the interior of the commissioners' room, in which these men meet Wednesday morning of each week, and it may be of interest here that these commissioners have, since the inception of this plant, been chosen from Erie's best business men. The water department is separate from the city government and under the entire control of the commissioners, who are appointed by the judges of the court. Without commenting on what the administration of affairs might be otherwise, we can testify that the conduct of the affairs of this department, since we have been connected with it in 1911, has been superb.

A room similar to the one shown has also been provided for the office of the water works superintendent.

The plant, built as it was in 1912 and 1913, during a period of depression and low prices, cost approximately only $11,500 per million gallons. This includes the filter plant, clear water basin, coagulant basins, and intervening piping.

The plant incorporates its own electric light plant, from which is obtained the energy for lighting the station, operating the coal and ash handling machinery, automatic sump pumps for both the pump station and the filter plant, hoisting the coagulants and other minor necessities.

Duty and efficiency tests were made on all the elements, a summary of which may prove of interest. The results follow:

Low service. Since the minimum consumption at the time of the rebuilding of this station was practically 12,500,000 gallons and the maximum contemplated for the facilities furnished was 40,000,000 gallons, the head was computed for a capacity of 12,500,000, 15,000,000, 20,000,000 and 40,000,000 gallons, and duty tests for the machinery specified for each capacity.

A summary of the tests of one pump and one test of the second pump as shown in table 1.

The question may here arise as to why turbine driven pumps were not employed for this service instead of the engine driven as purchased. The answer is that at the time the first two were purchased the specifications were open for bids on this type of equipment and none were received. At the time the third unit was purchased some years later the following bids were received:

Engine driven equipment	$14,700
(1) Turbine driven equipment	12,800
(2) Turbine driven equipment	15,185

TABLE 1

Summary of efficiency tests of low service pumps at Erie, Pa.

	PUMP 1				PUMP 2
	Test 1	Test 2	Test 3	Test 4	Test 3
Head specified	28 ft.	23 ft.	25 ft.	37 ft.	25 ft.
Head actual	26.87	23.34	29.22	38.29	30.48
Contract capacity, 24 hours	12,500,000	15,000,000	20,000,000	20,000,000	20,000,000
Actual capacity, 24 hours, gals	12,597,996	12,268,092	20,577,948	20,844,960	10,535,456
Duty guarantee, foot pounds	60,000,000	60,000,000	65,000,000	70,000,000	65,000,000
Duty obtained, foot pounds	63,636,000	63,426,000	69,486,000	75,554,000	68,294,300
Per cent exceeded	6.1	5.7	6.9	7.9	
Duty 1000 pounds, steam foot pounds	76,661,900	76,442,000	82,849,500	89,301,600	82,873,400
Unit efficiency	66.8	68.2	73.8	74.4	77.8

The guarantees were as follows:

		15,000,000 RATE AGAINST 24 FOOT HEAD	20,000,000 RATE AGAINST 30 FOOT HEAD	20,000,000 RATE AGAINST 40 FOOT HEAD
		foot pounds	*foot pounds*	*foot pounds*
Engine driven		62,000,000	68,000,000	74,000,000
Turbine driven	(1)	55,000,000	74,500,000	82,000,000
	(2)	60,000,000	68,000,000	65,000,000

On account of the space occupied and to preserve uniformity the conclusion was reached that the purchase of the engine driven equipment would best serve the interests of the water works department.

High service pumps. The results of the test of the Bethlehem pump on standpipe service are as follows:

Duty per 1000 pounds of steam....................204.9 mil. ft. lbs.
Per million heat units............................168.5 mil. ft. lbs.
Guaranteed duty per million heat units...........168.0 mil. ft. lbs.
Mechanical efficiency............................ 96.3 per cent
Slippage...1.255 per cent

The results on reservoir service were:

Duty per 1000 pounds of steam....................202.5 mil. ft. lbs.
Per million heat units...........................166.3 mil. ft. lbs.
Guaranteed duty per million heat units...........156.0 mil. ft. lbs.

On this last test, mechanical efficiency and slippage were not determined.

During both tests the steam pressure was kept above 195 pounds with the superheat at approximately 100°C. The pump head on the standpipe test was 347.8 feet and on the reservoir test 298.8 feet.

The boilers were built by the Heine Boiler Company who guaranteed an over-all efficiency of stokers, boiler setting, and superheaters of 71 per cent and on the test produced an efficiency of 71.59 per cent. The original purchase of boilers consisted of four 300-h. p. units set in two batteries of 600-h. p. each. In the guarantee the contractor agreed to accept the draft that would be furnished by the existing stack and breeching would be designed andfurnished by him. The stack was 8 feet in internal diameter at the top and 175 feet high. The coal used was to be any product that the contractor might demand from the mines within a radius of 100 miles of Erie. For the test Ridgway coal was selected.

Due to the heavy demands made on the plant during the war the commissioners, for safety, installed an additional 600-h. p. battery of boilers, which were supplied by the Erie City Iron Works. At this time the stoker plant was materially changed, the coal and ash handling facilities were extended, changed and remodeled.

Since the original installation, which incorporated all of the old pumps except the Cornish engines, the 12,000,000-gallon Worthington has been removed and the space occupied by it was taken by the two low service engine driven centrifugals, and a third unit added.

There has also been installed in this low service room a high service DeLaval turbo centrifugal 20,000,000-gallon unit, the function of which is to act as an alternate or standby unit for the Bethlehem engine, the demand over 20,000,000-gallons being ordinarily supplied by the 8,000,000-gallon horizontal high duty Worthington. It is of course possible, however, to operate both the Bethlehem and the DeLaval together, but this combination is infrequent.

The duty guaranteed for the DeLaval on the heat unit basis is 117,000,000 foot pounds, as compared with 168,000,000 foot pounds of the Bethlehem.

While duty guarantees must figure largely in guiding us at the time of purchase, the actual results achieved are the facts in which we

are interested. In order that they may be here set out, the authors of this paper have caused this plant to be operated four consecutive days with only the Bethlehem in operation and have followed this with four consecutive days with the DeLaval in operation. All data necessary to the computation of the duty were taken, with all elements of the plant, other than the main units, the same and all conditions relative, with exception of the boilers, since only two were required with the Bethlehem and three with the DeLaval. The tests resulted in a *station duty* as follows:

	BETHLEHEM	DELAVAL
Per 1000 pounds of steam	104,000,000	72,500,000
Per 100 pounds of coal	66,800,000	53,200,000

Assuming that the pumpage would average 18,000,000 gallons per day for the engine year, or that each engine would deliver 90 per cent of its rated capacity throughout its life, and fixing interest and depreciation at 7 per cent, the following excesses, varying with the price of coal, could be invested in a reciprocating triple expansion over a turbo driven centrifugal.

$2.00	$3.00	$4.00	$5.00
107,400	161,100	214,800	268,500

or assuming the life of the reciprocating engine at thirty years and the turbo driven centrifugal at twenty and money to be worth 5 per cent and that the turbo centrifugal could be bought for $40,000, which is the approximate pre-war price, then the following investments for the different prices of coal could be warranted in order to install a reciprocating engine.

$2.00	$3.00	$4.00	$5.00
164,910	222,700	280,485	338,270

The Bethlehem engine was purchased in 1912 for $102,000. An estimate obtained on a turbo centrifugal after the war in Europe had broken out was slightly under $40,000. The machine in service was purchased in 1916 for $51,500.

With respect to the discharge piping around the station due to the numerous cut-ins, alterations, etc., the result of forty years operation, the commissioners in 1916 decided to replace the maze of complications and to simplify conditions. A design was prepared, therefore, for two discharge mains, one 48 inches and the other 36 inches diameter, either of which could be used for high or low service and so arranged that all pumps delivered into either. These new improvements extended to the top of the hill, or a distance of some 400 feet from the remote end of the pumping station.

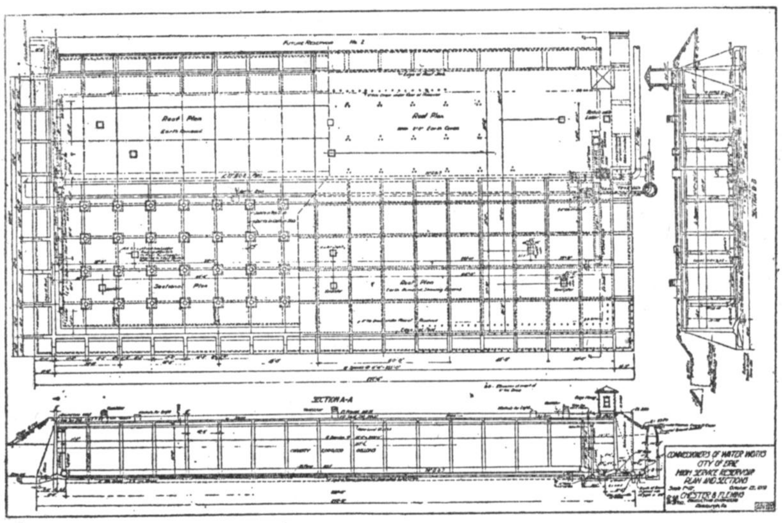

FIG. 5

The original plan for the rebuilding of this plant, while incorporating a standpipe for the high service, was to serve for a time or until funds would be forthcoming for a reservoir. A standpipe was so designed that all of the water could be pumped through the same. When the head reached a certain height the standpipe overflowed into the reservoir, but all pipe was so arranged and gated that the high and reservoir service would be entirely independent, as conditions with respect to cost might show most expedient. In the engineers' report it was declared impossible to decide which plan would be the cheaper. This statment was later confirmed in actual operation when the figures were so close that one method might prove cheaper one week and the other the next.

In 1920 the commissioners let a contract for a 5,000,000-gallon reinforced concrete covered high service reservoir, which will be completed and put in service in the fall of 1921. The only feature in which this reservoir differs from numerous others of this country is that, although numerous test holes were dug over the site and an excellent clay bottom revealed, when the excavation for the structure was brought down to sub-grade, it was discovered that the subgrade approached, in some cases, within a few feet of the soft mud stratum. The thickness of the overlying clay between the subgrade and this mud stratum varied over the entire area from approximately 3 feet to 10 or 12 feet, but at no place did it afford a supporting power necessary for such a structure. As a result piles had to be driven over the entire area, thus increasing materially the actual cost over the estimated. A general plan and cross section of this reservoir are shown in figure 5.